DEVELOPMENT OF ALTERNATIVE FORCE CONVERTER FOR ELECTRIC GENERATOR USES

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ABSTRACT

In this thesis, the objective is to design a new concept of a prototype force converter, analyze the mechanism to manipulate the energy, and fabricate the prototype based on the approved mechanism design. Buoyancy force has been chosen based on better characteristic compare to conventional energy resource to be converted into torque to rotate the dynamo before the electricity can be generated. The only changed in this mechanism design is at air trap mechanism, this is the most important part to archive higher efficiency in producing electricity. Theoretically, within this design it can produce maximally 111 N.m torque. Based on the analysis toward this alternative force converter, net power output that can be generated by this machine is 450 W.

ABSTRAK

Objektif dalam tesis ini adalah untuk mereka bentuk prototaip penukar tenaga berasaskan konsep baru, melakukan analisis terhadap mekanisma yang telah direka bentuk dan melaksanakan fabrikasi berdasarkan reka bentuk yang telah diluluskan. Didalam kajian ini, daya apungan telah dipilih sebagai sumber tenaga baru berdasarkan kepada ciri – ciri nya yang lebih baik berbanding sumber tenaga konvensional untuk diubah kepada daya kilasan bagi memutarkan dynamo sebelum tenaga elektrik dijanakan. Reka bentuk yang berubah hanyalah pada bahagian mekanisma perangkap udara kerana bahagian ini merupakan bahagian terpenting bagi menentukan kecekapan mesin dalam menghasilkan tenaga elektrik. Pada teorinya reka bentuk ini mampu membekalkan daya kilasan maksima sehingga 111 N.m. Berdasarkan kepada analisis yang telah dijalankan terhadap mekanisma penukar tenaga alternatif ini, kapasiti tenaga elektrik bersih yang dapat dihasilkan adalah sebanyak 450 W.

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LIST OF SYMBOLS

F	Force
e	Density
v	Velovity
g	Gravity
W	Weight
m	Mass
h	Height
F_{net}	Net Force
τ	Torque
r	Radius
n	revolutions or rev/min
N	number of teeth
d	pitch diameter
$F.S$	Factor of safety
μ	Dynamic viscosity
Re	Reynold's number

CAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Nowadays, there are lot types of alternative electric generator. The primary different between all of this alternative electric generator is the way how the mechanical system converting the natural energy to the type of force needed and the type of alternative energy uses. Alternative energy here is a term used for some energy source that is an alternative to using fossil fuels. Generally, it indicates energies that are non-traditional and have low environmental impact. The term alternative is used to contrast with fossil fuels according to some sources, and some sources may use it interchangeably with renewable energy. Renewable energy such as sunlight, wind, rain, tides and geothermal heat are commonly use in producing electric but most of this source of energy are not consistently available such as sunlight, wind, rain and tides.[13]

Alternative Force Converter is a mechanical system uses to convert the natural energy to the types of force needed to run the alternator. Most of the conventional electric generators are using combustion engine and steam turbine to convert the heat energy to the force needed to run the alternator, but an alternative electric generator are using different mechanical system to convert different types of energy, such as wind power or wind mill it use the wind turbine or blades to convert the wind energy into electricity, solar power are using either two ways to produce an electricity, there are photovoltaic method or conventional method by heating transfer fluid to produce steam

to run the an alternator and the latest one is a wave power, it use sea wave to produce an electricity with unspecified method used.

For my prototype Alternative Force Converter, it applied different mechanism to convert the energy and used different energy source or force then current alternative electric generator used. My prototype Alternative Force Converter used buoyancy force as a renewable energy source to run the alternator. This buoyancy force is only move in one axis of direction which is in x-axis direction. So using a specific mechanical system, this linear motion of force will be converting into angular motion of force or torque. This torque is very useful to run the alternator because the alternator is only operating in an angular type of motion.

1.2 PROBLEM STATEMENT

The current alternative electric generator are using inconsistent energy source to produce electricity, this will cause an inconsistent amount of electricity produce in one time.

1.3 OBJECTIVE OF THE PROJECT

I. Design a new concept of prototype force converter.
II. Analyze the mechanism design.
III. Fabricate a new concept of prototype alternative force converter.

1.4 PROJECT SCOPE

This project is focus on development of a new concept of prototype alternative force converter and it consists of studying, designing and fabricating a prototype alternative force converter. This focus area is done based on the following aspect:

I. Studying for the new type of renewable and reliable source of energy or force to run the alternator.
II. Design a new concept of prototype force converter suitable to the selection renewable source of energy or force.
III. Studying the concept of design of the prototype force converter mechanism.
IV. Do the analysis and simulation.
V. Fabricate a prototype of alternative force converter.

CAPTER 2

LITERATURE ANALYSIS

2.1 ALTERNATIVE FORCE CONVERTER

Alternative Force Converter is a mechanical system uses to convert the natural energy to the types of force needed to run the alternator. Most of the conventional electric generators are using combustion engine and steam turbine to convert the heat energy to the force needed to run the alternator, but an alternative electric generator are using different mechanical system to convert different types of energy, such as wind power or wind mill it use the wind turbine or blades to convert the wind energy into electricity, solar power are using either two ways to produce an electricity, there are photovoltaic method or conventional method by heating transfer fluid to produce steam to run the an alternator and the latest one is a wave power, it use sea wave to produce an electricity with unspecified method used.

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2.2 FORCE

Force is what causes a mass to accelerate. In everyday life force is determine as a pull, a push or a twist. Force has direction and magnitude that is classified as vector quantity. The net force is the vector sum of all force acting simultaneously on an object. Net force is referring as resultant force or the unbalanced force. Net force is mathematically equal to the time rate of change of the momentum of the body on which it acts. In an extended body, force may also cause rotation, deformation, or a change in pressure. Rotational effects are determined by the torques, while deformation and pressure are determined by the stresses that the forces create. There are three laws that hold the force mean, there are Newton's first law, Newton's second law and Newton's third law. [4]

2.3 ENERGY

Energy is present in the universe in a variety forms, including mechanical, chemical, electromagnetic, and nuclear energy. Energy can be transformed from one kind to another, the total amount of energy in the universe is never change which mean it can not be destroy or created. If one form of energy in an isolated system decreases, then another form of energy in the system must increase. There are two form of energy which is kinetic energy and potential energy. [15]

2.4 RELATIONSHIPS BETWEEN FORCE AND ENERGY

In my project, both force and energy can be related by the work done of the air trap. The air traps contain an air inside it to provide buoyancy force. This buoyancy force will sent the air trap to the surface which is lower pressure. In my design, the alternative force converter contains 10 air traps which 4 air trap at the right side (contain air), other 4 at the left side (contain no air), 1 at top side and the last one at the bottom side (refer figure 4.7 and 4.8). The water tank is about 1.5 meter and each air trap is about $0.034375m^3$. Using the work formula mgh or Fh, it will provide about 472.108 J each air trap.

(Refer Solidwork analysis)

Volume of air in 1 unit air traps = $0.25 \times 0.25 \times 0.55 = 0.034375m^3$

$F_{buoyancy} = \rho vg$

$= 1000 \times 0.034375 \times 9.81$

$= 337.22N$

$W = mgh$

$= Fh$

$= [(0.034375m^3)\ (9810N)] \times 1.4m$

$= 472.108\ J$

2.5 RENEWABLE SOURCE OF ENERGY

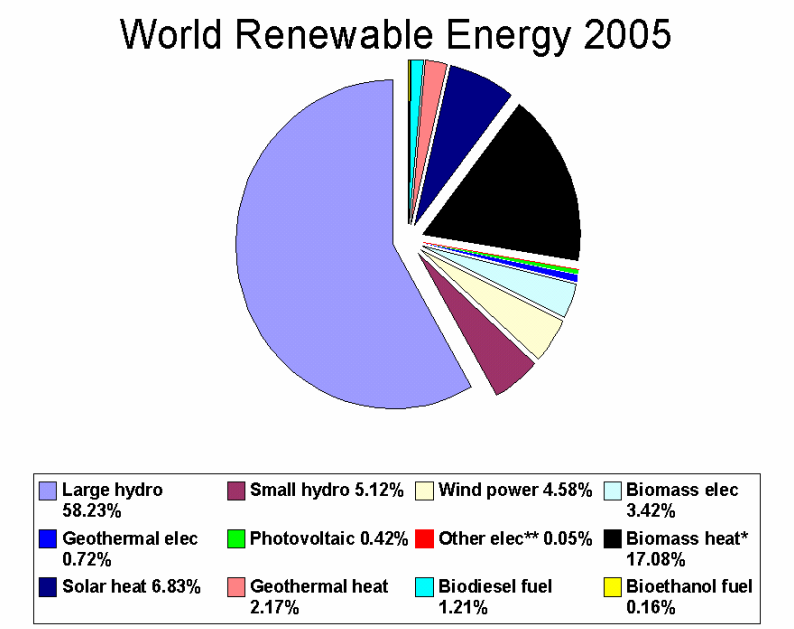


Fig 2.1 World renewable energy 2005

Renewable energy effectively uses natural resources such as sunlight, wind, rain, tides and geothermal heat, which are naturally replenished. Renewable energy technologies range from solar power, wind power, hydroelectricity/micro hydro, biomass and biofuels for transportation. In 2006, about 18 percent of global final energy consumption came from renewable, with 13% coming from traditional biomass, like wood-burning. Hydropower was the next largest renewable source, providing 3%, followed by hot water/heating which contributed 1.3%. Modern technologies, such as geothermal, wind, solar, and ocean energy together provided some 0.8% of final energy consumption. The technical potential for their use is very large, exceeding all other readily available sources. [16]

2.5.1 Wind Power

Wind is the flow of air. More generally, it is the flow of the gases which compose an atmosphere. Simply it occurs as air is heated by the sun and thus rises. Cool air then rushes in to occupy the area the now hot air has moved from. When a difference in pressure exists between two adjacent air masses, the air tends to flow from the region of high pressure to the region of low pressure. On a rotating planet, flows will be acted upon by the Coriolis force, in regions sufficiently far from the equator and sufficiently high above the surface.[14] The differential heating drives a global atmospheric convection system reaching from the Earth's surface to the stratosphere which acts as a virtual ceiling. Most of the energy stored in these wind movements can be found at high altitudes where continuous wind speeds of over 160 km/h occur. This wind energy then used to rotate the blade that attach to the turbine and finally produce the electricity. There is an estimated 72 TW of wind energy on Earth that potentially can be commercialized. [10]

2.5.2 Hydro Power

The energy came from water can be divide into two types, there are potential energy and kinetic energy. Potential energy from the dammed water is the energy extracted from the water depends on the volume and difference in height between the source and the water outlet. This height difference is called the head. The amount of potential energy in water is proportional to the head. The higher the level of water from the release valve, the higher potential energy will be produced. Kinetic energy from the waterwheel is the energy extracted from the water depends on the velocity of the water flow in the river. The higher velocity of the water river, the higher kinetic energy will be produced. [15]

2.5.3 Solar Power

Solar energy is energy directly from the Sun. Earth receives 174 petawatts of incoming solar radiation at the upper atmosphere at any given time. When it meets the atmosphere, 6 percent of the insolation is reflected and 16 percent is absorbed. Average atmospheric conditions such as clouds, dust, and pollutants, further reduce insulation traveling through the atmosphere by 20 percent due to reflection and 3 percent via absorption. These atmospheric conditions not only reduce the quantity of energy reaching the earth's surface, but also diffuse approximately 20 percent of the incoming light and filter portions of its spectrum. After passing through the atmosphere, approximately half the insolation is in the visible electromagnetic spectrum with the other half mostly in the infrared spectrum which a small part is in ultraviolet radiation. The total solar energy available to the earth is approximately 3850 zettajoules (ZJ) per year. Oceans absorb approximately 2850 ZJ of solar energy per year and the other is absorbed by the land field. Solar energy can be extract using two methods, there are heat transfer method and photovoltaic method. [1]

2.5.4 Biofuel

Biofuel is a basic abbreviation of biorganic fuel. Biofuel is an alternative considered to replace petroleum gas consist of *gasoline* and diesel. There are two types of biofuel which is in liquid and solid form. They are many ways to produce liquid biofuel, first is by extracting the vegetable to get their oil and this biofuel only can be work in warm condition. Other famous biofuel is biodiesel, it is produced from oils or fats using transesterification and is a liquid similar in composition to mineral diesel. Its chemical name is fatty acid methyl or ethyl ester (FAME). Oils are mixed with sodium hydroxide and methanol or ethanol and the chemical reaction produces biodiesel (FAME) and glycerol. 1 part glycerol is produced for every 10 parts biodiesel. Other is ethanol fuel, the ethanol production methods used are enzyme digestion to release sugars from stored starches, fermentation of the sugars, distillation and drying. The process

requires significant energy input for heat. Solid biofuel is a fuel in a solid form such as wood, manure and charcoal.

2.5.5 Geothermal Power

There are three different type of method used to generate electricity from geothermal energy. It consists of dry steam, flash and binary method. This all are depending on temperature, depth, and quality of the water and steam in the area. The higher temperature and quality of the water and steam, the higher energy can be extracted. In all cases the condensed steam and remaining geothermal fluid is injected back into the ground to pick up more heat. In some locations, the natural supply of water producing steam from the hot underground magma deposits has been exhausted and processed waste water is injected to replenish the supply. [8]

2.5.6 Wave Power

Waves are generated by wind passing over the sea and the gravity of Moon effect on Earth. Organized waves form from disorganized turbulence because wind pressure pushes down wave troughs and lifts up wave crests, the latter due to Bernoulli's principle. Wave power is determined by wave height, wave speed, wavelength, and water density. Wave size is determined by wind speed and fetch (the distance over which the wind excites the waves) and by the depth and topography of the seafloor (which can focus or disperse the energy of the waves). A given wind speed has a matching practical limit over which time or distance will not produce larger waves. Wave motion is highest at the surface and diminishes exponentially with depth; however, wave energy is also present as pressure waves in deeper water. The potential energy of a set of waves is proportional to wave height squared times wave period. Longer period waves have relatively longer wavelengths and move faster. The potential energy is equal to the kinetic energy that can be expended. Wave power is expressed in kilowatts per meter. [13]

2.5.7 Comparison of Energy Resource Reserve

Table 2.1: Energy resource base (exajoules per year)

Types of source of energy	Current used (2001)	Technical potential	Theoretical potential
Hydropower	9	50	147
Biomass energy	50	> 276	2900
Wind energy	0.12	640	6000
Solar energy	0.1	> 1575	3900000
Geothermal energy	0.6	5000	140000000
Ocean energy	Not estimated	Not estimated	7400
Nuclear energy	0.04	330	433
Buoyancy force	0< n <0.0001	Not estimated	1248366
Total	60	> 7600	> 151000000

Source: [10]

There are many types of source of energy that can be used to be converted into electricity such as hydro power, biomass energy, wind energy, solar energy, geothermal energy, ocean wave energy, nuclear energy and others. Currently, biomass energy is the most chosen source of energy to be converted into electricity and nuclear energy is the less to be used to produce electricity. The different in quantity of energy used to produce electricity exist because of the many factors, and according to the table 2.2, complexity of the mechanism to manipulate the energy is the most critical factor that affect this differences.

As shows in table 2.1, there are about 1248366 exajoules per year reserve for buoyancy force as energy resources. Current used of this energy to be converted into electricity is almost equal to zero or may approximately equal to zero, because current technology never used buoyancy force as a source of energy to produce electricity. So we can conclude that buoyancy force is the most abundant source of energy to be used as a medium to produce electricity.

2.5.8 Comparison of Various Types Electric Generator and Power Plant

Table 2.2: Characteristic of electric generator and power plant

Type of electric generator	Energy source used	Operation and maintenance cost	Mechanism complexity	Type of pollution produced	Geography effect	Man skill required	Space required in equivalent capacity
Wind mill	Wind	Low	simple	-	-	Less	Very Large
Solar panel	Solar	High	Complex	-	-	Moderate	Very Large
Wave generator	Sea wave	Moderate	Moderate	-	-	Less	Large
Diesel generator	Diesel	Moderate	Moderate	Air pollutant	-	moderate	Moderate
Thermal power plant	Earth mantle	High	Complex	-	Bad	High	Moderate
Hydroelectric power plant	Water potential energy	Low	Simple	-	Very bad	Moderate	Very Large
Nuclear power plant	Nuclear reaction	Very high	Very complex	Uranium mining and wasted heat	bad	Very high	Large
Buoyancy force electric generator	**Buoyancy force**	**Low**	**Simple**	-	-	less	Moderate

Source: [9, 11, 12]

Based on table 2.2, there are many factor need to be consider before an electric generator or electric power plant is going to be develop, such as type of energy source used to produce electricity, operation and maintenance cost, complexity of plant or generator mechanism, type of pollution produced, effect on geography, man skill required and space required in equivalent capacity of electric to be generated.

From table 2.2, the most highest point in all characteristic is nuclear power plant, because this kind of technology are still new and need more research to increase the efficiency of the operation and also need very high safety and precaution consideration while developing and operating the power plant. Buoyancy force electric generator is the best electric generator to be developed in term of energy source uses, simple in mechanism complexity, zero pollution produced, and low in maintenance, operation, and manufacturing cost

2.5.9 The Advantages of Renewable Energy

There are several advantages if renewable source of energy is use widely as conventional energy. Within this kind of energy, it can mitigate climate change. From the data, CO2 emissions growing 0.5 per cent rate per year and if nothing to do with it, by 2050 it will doubling atmospheric concentration and causing climate change.

The rapidly growing of renewable energy industries in many countries show increasing in technology innovation, economy and creation of new job in different qualification requirements.

Today energy industries security comes at high cost, and the price can be affected dramatically by the global situation or condition especially if the energy came from fossil fuels. So that renewable energy is the best solution to prevent conflict about natural resources.

Combustion of fossil fuels emitted sulphur, nitrogen oxides, carbon monoxide and suspended particulate matter. All of these gases cause global warming when the heat from the Sun can not be deflected from course efficiently. It also causes ozone precursors and acid deposition that threatened human health very badly and this will not happen if the renewable energy takes place the conventional energy position. [2]

2.5.10 My Renewable Source of Energy

From all of the information above, I decided to use buoyancy force as my renewable source of energy. Generally buoyancy is the upward force on an object produced by the surrounding fluid either liquid or gases, in which it is fully or partially immersed, due to the pressure difference of the fluid between the top and bottom of the object. The net upward buoyancy force is equal to the magnitude of the weight of fluid displaced by the body. This force enables the object to float or at least to seem lighter.

i. Why This Kind of Renewable Source of Energy is Chosen.

From my research, buoyancy force is the most abandon energy to be use in generating the electricity, but this kind of force has been use in many other applications especially in floating the ship, floating the offshore oil platform, weather balloon, and safety jacket. The buoyancy of an object is depends on two factors, first is the object's submerged volume, and, the density of the surrounding fluid. The greater the object's volume and surrounding density of the fluid, the more buoyant force it experiences. Thus the magnitude of the buoyant force is simply equal to the weight of the displaced fluid. In this context, displacement is the term used for the weight of the displaced fluid and, thus, is an equivalent term to buoyancy. [15] If we have $1m^3$ of air in the water medium it can provide about 9810N of buoyancy force and if we multiply with 2m we can get about 19620 joule of energy, it is quite impressive compare to their size (1 x 1 x 2) m^3 and we divide by 5s, we can get about 3924W which is equal to maximum power of 16 normal man and can power up about two medium size of houses. This buoyancy force can be archive by supplying the air using an air compressor into a tank of water, and the air is trapped into a special air trap mechanism that will provide continuous rotation of the shaft and further convert it into electricity. It also does not produce any waste or pollutant or we call it as “total green house renewable energy” because it does not need any chemical reaction also heating process to produce electricity as existing alternative electric generator did. Beside that, the cost of source of energy are very low or equal to zero because I am using cycle energy to provide buoyancy force.

2.6 BUOYANCY FORCE

The increase in hydrostatic pressure with depth in a fluid creates a net force on an immersed object. The net vertical force acting on an object due to hydrostatic pressure is called the buoyancy force. Archimedes' principle states that a buoyancy force, $F_{buoyancy,}$ acts in the direction opposite to that of the gravitational force, $F_{gravity}$, and has a magnitude equal to the weight of the displaced fluid. Figure 2.2 indicates that the buoyancy force arises because the increase in hydrostatic pressure with depth creates a net upward hydrostatic force on the surface of the object. Since the gravitational force on the object is equal to its weight, the net force F_{net} on a submerged object is the difference between its weight W_{object} and the weight of the displaced fluid W_{fluid}. That is, we can write the net force as

$$F_{net} = F_{gravity} - F_{buoyancy} = W_{object} - W_{fluid}$$

Note that a positive value of F_{net} represents a net force in the direction of the gravitational field. A negative value implies that the object is being pushed upward in the opposite direction. This principle may be used to estimate the buoyancy force is the difference in the weight of the volume of hot fluid and the weight of an equal volume of the surrounding colder fluid. [3]

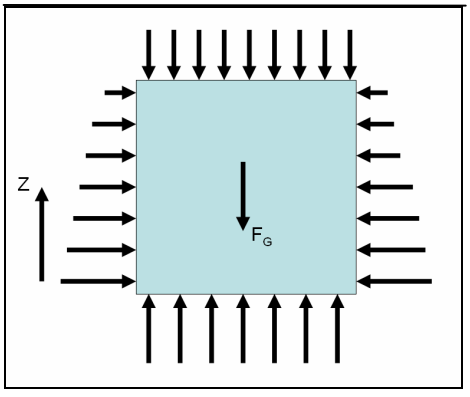


Fig 2.2 Hydrostatic pressure (increase with depth)

Calculation:

(Refer Solidwork analysis)

Volume of 1 unit air trap = (3.48e-005 x 4) + (6.89e-006 x 4) + (4.5e-005) + (4.2e-005 x 4)

$= 0.00038m^3$

Volume of 10 unit air traps = $0.00038 \times 10 = 0.0038m^3$

Volume of air in 4 unit air traps = $(0.25 \times 0.25 \times 0.55) \times 4 = 0.1375m^3$

Total displaced water = $0.0038 + 0.1375 = 0.1413m^3$

$e_{water} = 1000kg/m^3$

Total $F_{buoyancy} = evg$

$= 1000 \times 0.1413 \times 9.81$

$= 1386.153N$

Buoyancy force displaced by the 10 unit air traps = $1000 \times 0.0038 \times 9.81$

$= 37.278N$

Total $F_{buoyancy} = F_{buoyancy\ displaced\ by\ air} + F_{buoyancy\ 10\ air\ traps} = 1386.153N + 37.278N$

$= 1423.431N$

$F_{gravity} = (0.094 \times 9.81 \times 4) + (0.0186 \times 9.81 \times 4) + (0.121) + (0.113 \times 9.81 \times 4)$

$= 8.97N$

$= 8.97N \times 4$

$= 35.88N$

$F_{net} = F_{gravity} - F_{buoyancy}$

$= 35.88N - 1423.431N = -1387.551N$

So, this net force is used to float the air traps upward and further cause the shaft to rotate continuously.

2.7 TORQUE

Torque is a vector that measures the tendency of a force to rotate an object about some axis. The magnitude of a torque is defined as force times the length of the radius. Just as a force is a push or a pull, a torque can be thought of as a twist.

$$\tau = Fr$$

τ = torque

F = Force

r = radius

Calculation:

If the net torque or sum torque is equal to 0, the system is in equilibrium condition.

Torque at the 1st gear

$$\tau_{1st\ gear} = Fr$$

$$\tau_{1st\ gear} = (1387.55)(0.08)$$

$$\tau_{1st\ gear} = 111.004 N.m$$

Torque at the final gear

$$\tau_{final\ \ gear} = \tau_{1st\ gear}\left(\frac{1}{\left[\frac{r_2}{r_3}\frac{r_4}{r_5}\frac{r_6}{r_7}\frac{r_8}{r_9}\frac{r_{10}}{r_{11}}\right]}\right)$$

$$\tau_{final\ \ gear} = 111.004\frac{1}{\left[\left(\frac{0.08}{0.0275}\right)^5\right]}$$

$$\tau_{final\ \ gear} = 0.533 N.m$$

Minimum torque needed to run the dynamo

$$\tau = Fr$$

$$\tau = (9.81)(0.08)$$

$$\tau = 0.269775 N.m$$

Net torque

$$\tau_{net} = \tau_{final\ gear} - \tau_{required}$$

$$= 0.533N.m - 0.27N.m$$

$$= 0.263N.m$$

Net torque is equal to 0.263N.m, so that the system wills run as expected.

2.8 GEARING TRAINS

A gear train is a set or system of gears arranged to transfer rotational torque from one part of a mechanical system to another. Gear trains consist of driving gears, driven gears and idler gears. Driving gear is gear that attached to the input shaft, whereas driven gears is gear that attached to the output shaft and the idler gear is gear that interposed between the driving and driven gear in order to maintain the direction of the output shaft the same as the input shaft or to increase the distance between the drive and driven gears. A compound gear train refers to two or more gears used to transmit motion. If there is an idler gear, it can be canceled out in speed calculation because it only effect on the direction of the final gear rotation. Consider a pinion 2 driving a gear 3. The speed of the driven gear is. [7]

$$n_3 \left| \frac{N_2}{N_3} n_2 \right| = \left| \frac{d_2}{d_3} n_2 \right|$$

Where;

n = revolutions or rev/min
N = number of teeth
d = pitch diameter

Calculation:

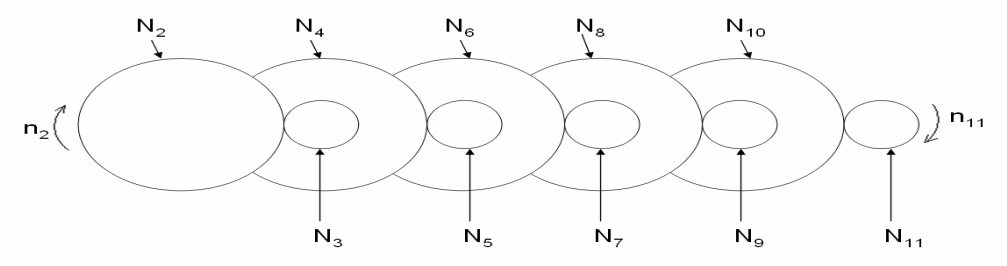


Fig 2.3 Gear trains

Base on design measurement, the shaft will revolve 4.78 times in every 1 complete revolution of the chain.

$= (950 \times 2) + (2 \times \prod \times 80)$

= 2402.65mm

Gear circle = 502.65mm

= 2402.65 / 502.65 = 4.78 rev

Estimation; 1 revolution of chain = 10s

So, 4.78 rev = 10s

$$\frac{4.78 rev \times 60 s}{10 s} = 28.68 \text{ RPM}$$

In the worse case, assumption n_1 = 20 rpm

Hence we notice that gear 2,3,4,5 is an idler, which its tooth numbers cancel because it only effect on the direction of the final gear (gear 6).

$$n_{11} = \frac{N_2}{N_3}\frac{\cancel{N_3}}{\cancel{N_4}}\frac{N_4}{N_5}\frac{\cancel{N_5}}{\cancel{N_6}}\frac{N_6}{N_7}\frac{\cancel{N_7}}{\cancel{N_8}}\frac{N_8}{N_9}\frac{\cancel{N_9}}{\cancel{N_{10}}}\frac{N_{10}}{N_{11}} n_2$$

$$= \frac{N_2}{N_3}\frac{N_4}{N_5}\frac{N_6}{N_7}\frac{N_8}{N_9}\frac{N_{10}}{N_{11}} n_2$$

$$= \frac{48}{15}\frac{48}{15}\frac{48}{15}\frac{48}{15}\frac{48}{15}(20 rpm)$$

= 3.2 x 3.2 x 3.2 x 3.2 x 3.2 x 20

= 6711 rpm

2.9 FACTOR OF SAFETY (SOF)

Factor of safety is mean the fracture structural capability over the maximum expected load required to which a component or assembly will be subjected. There are two senses of the term that are completely different between the each other. The first is a measure of the reliability of a particular design, while the second is a requirement imposed by law, standard, contract or custom. Appropriate factors of safety are based on several considerations. Prime considerations are the accuracy of load, strength, and wear estimates, the consequences of failure, and the cost of over engineering the component to achieve that factor of safety. Critical component or subject that could result a serious injury or death and substantial financial loss usually used factor of safety of 3 to 10, and for the non – critical component such as toy, plate, speaker and spoon generally used design factor of 2. The higher value of factor of safety, the higher manufacturing cost indeed, but if there are too small factor of safety value and not suitable for the product or structural it will cause a disaster, so in order to setting up the factor of safety value, engineer must consider everything that can effect the product ability. [5]

Ratio of the ultimate load to the allowable load used to defined factor of safety

$$Factor\ of\ \ safety = F.S = \frac{ultimate\ load}{allowable\ load}$$

Alternative factor of safety based on the stresses

$$Factor\ of\ \ safety = F.S = \frac{ultimate\ stress}{allowable\ stress}$$

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In order to complete all the tasks in developing prototype Alternative Force Converter, methodology is one of the most important thing to be considered as a guideline to make sure the entire task can be done on time and finally archive all the objective required.

In methodology, the structure of development is a significant thing that should be considered. Methodology also can be described as a framework of the research that contains the elements of work based on the scope and the objectives. Frameworks also use to facilitate the supervisor to view the overall process of the development. Any mistaken or lacking in the development process can be detected and further more correcting it.

3.2 FLOW CHART

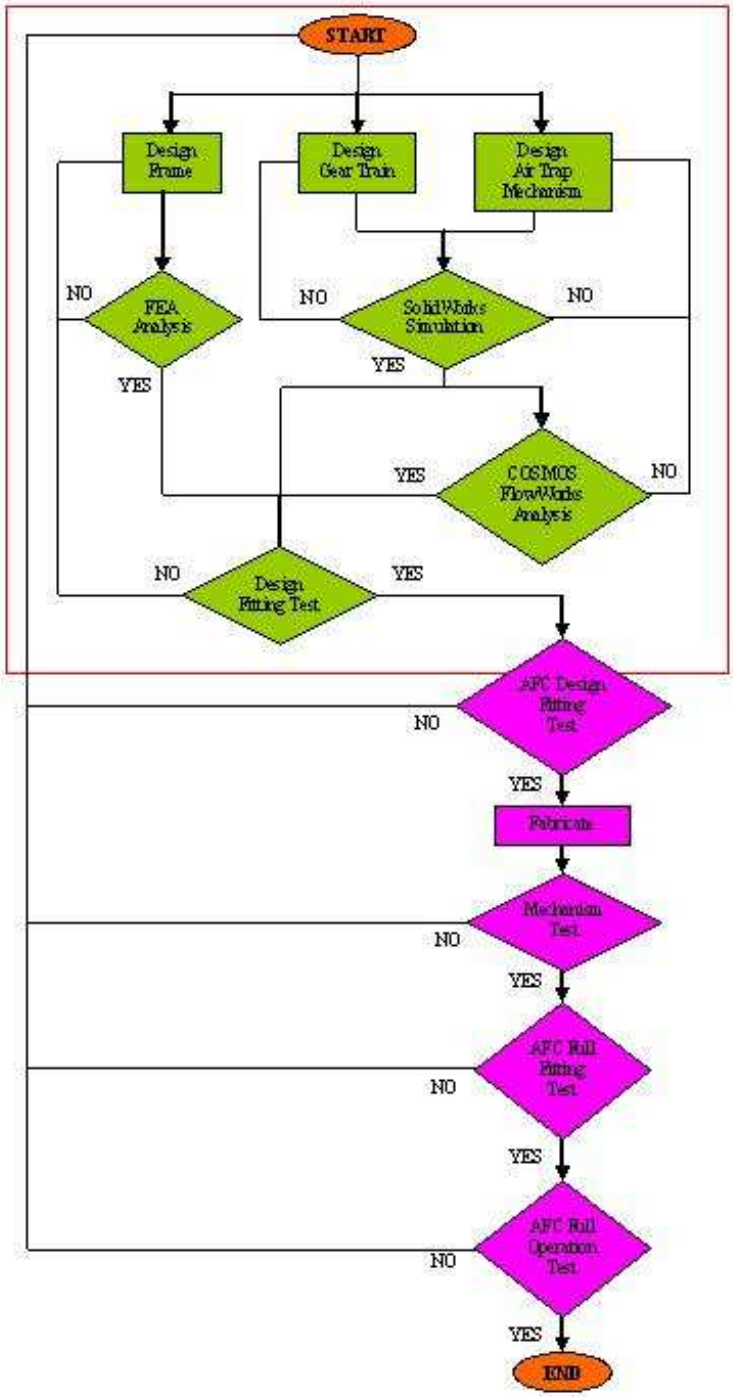


Fig 3.1 Flow chart

3.3 LITERATURE ANALYSIS

Literature analysis is a combination of literature review and analysis toward the product to be developed. To start this project it is very important to understand the title of the project propose, which is to understand all the concept of alternative force converter including gear train, buoyancy, and design concept. In order to understand that, the best and precise information must be gathered from the right source. There are several methods to get all the information required.

1) Surfing the internet
2) Books
3) Discussion with supervisor

3.3.1 Internet

Internet is the most easies way to gather the information about the project. From the internet, correct information can be fine from the journal gathered by trusted web page such as science direct and other World Wide Web information data such as wikipedia and answer.com. But not all of this information can be trusted 100 percently, so, the data must be compared to the relevant book before it collected.

3.3.2 References Books

Reference books are the most trustable and precise sources to be used because it is written by the professional class person such engineer and doctor that is very well in their course. All the data such as analysis, concept and calculation method can be found in the book.

3.3.3 Discussion With Supervisor

Although all the data gathered from the internet and reference book is enough, discussion with supervisor also very important to make sure that all of the information gathered is correct and related to the project title. Furthermore, discussion with supervisor can generate new idea for the project research beside make the research more clear and understandable.

3.4 IDENTIFY THE PROBLEM AND PROVIDE SOLUTION.

In this project, the most important thing is to understand the whole concept of the alternative force converter and what are the weaknesses of the previous force converter. From that, we can develop more efficient and less pollution alternative force converter. Source of energy is one of the most important things to be considered. Current electric generator mostly used in-renewable source of energy or force and a few of them use renewable source of energy but there is one problem, most of the renewable source is inconstantly supplied.

Mechanisms to manipulate the source of energy become the second most important things to be solved. Mechanism contains a variety of mechanical systems to convert the natural force to the type of force needed which mean torque. The higher torque and speed produce by the force converter the higher electric power produced by the electric generator.

Safety of factor becomes a third thing to be considered. Every problem in the concept design should be solved before the product design to be realized. This can be solved by doing some simulation and analysis toward the product design such as using COSMOS or ALGOR.

3.4.1 Design The Force Converter Mechanism

For my force converter prototype, I decided to use buoyancy force as a source of energy to run the electric generator alternator. There are three major conditions to be considered in designing the force converter mechanism. First is enough torque and high speed shaft rotation. The higher torque and speed produce by the force converter the higher electric power produced by the electric generator. In order to archive that condition is by designing an efficient gear train.

Second is high buoyancy force supply. The higher buoyancy force contained, the higher torque provided by the last gear component. In order to archive that condition is by selecting the best two different fluids that have different density in opposite side in addition having low stickiness properties. Beside that is design an effective mechanism to contain the lower density fluid.

Third is less operation cost. This condition can be archive by selecting the best renewable source of energy, designing an effective and simple force converter mechanism, select an existing part as a partial of the product component and less man power to operate and provide maintenance to the alternative force converter.

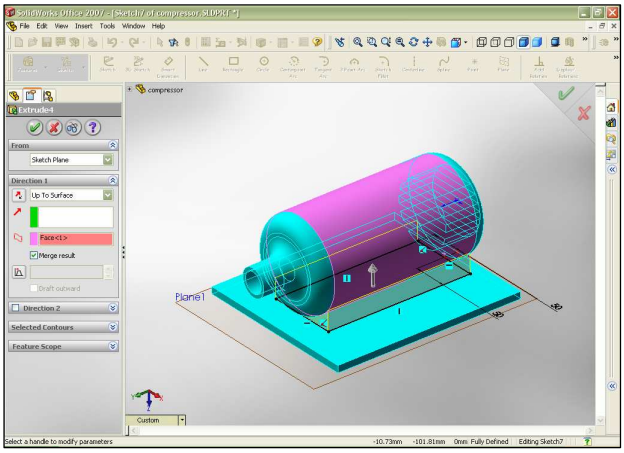


Fig 3.2 Design alternative force converter using Solidwork CAD software

3.4.2 Safety of Factor

Safety of factor is the most significant reason why engineers do the simulation and analysis before the product is fabricated. From the simulation and analysis result, we can predict the consequence of the real product operation. By using simulation, we can check either what we have imagined before is correct or not especially the mechanism design. From the product analysis such as strain stress analysis, CFD analysis and strength analysis we can know either the material or design chosen is safe or not furthermore to decrease the probability of the product to be fail.

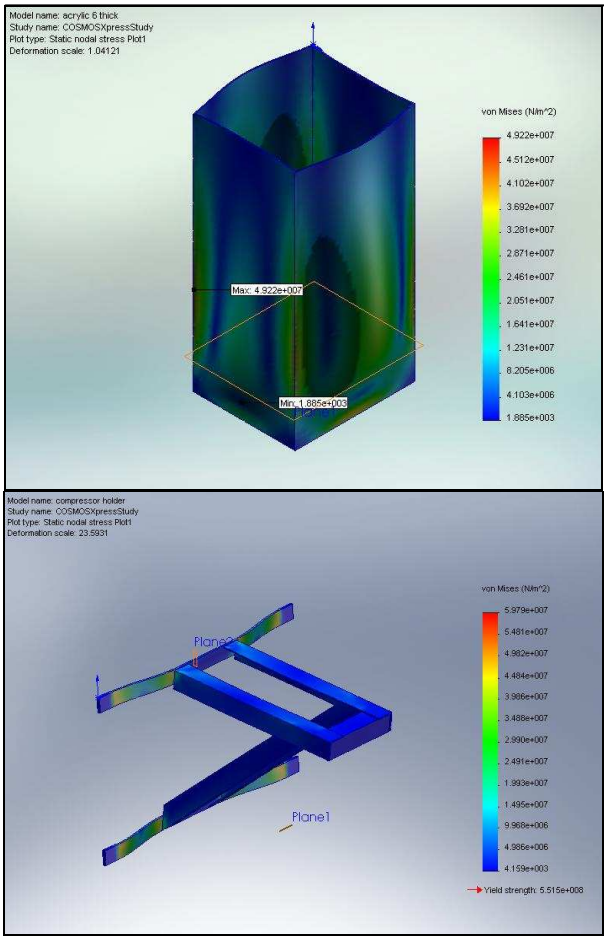


Fig 3.3 Finite element analysis using COSMOS software

3.5 PROPOSED THE BEST DESIGN

Well design is very important to verify either the project is success or not. The best design came from the best idea and imagination followed with comprehensive simulation and analysis. From the analysis and simulation we can detect if there any problem with the product design and further improve the design to make it perfect.

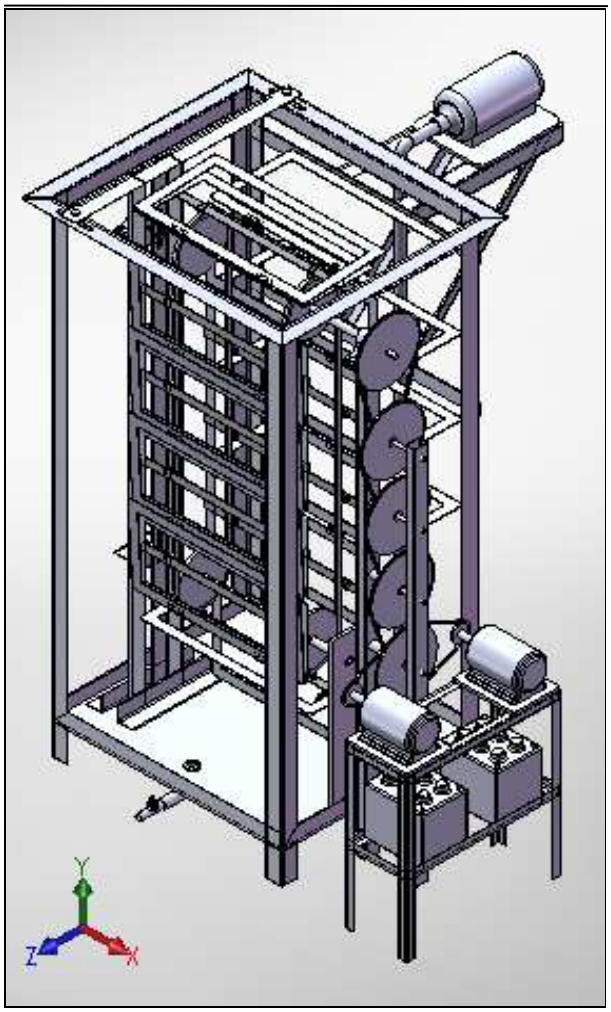


Fig 3.4 Alternative force converter

3.6 FABRICATE AND RUN THE PRODUCT TESTING

After the design stage completed, the prototype fabrication is the next step. By fabricating the prototype, we can test the real working prototype and verified either the product can really work in the real world, because in the real world, their condition is not exactly same as in virtual world such as in ALGOR and SOLIDWORK simulation. Beside that the real product testing will give a clear view of the mechanism operation and from that we can identify any other problem or weaknesses of the prototype product, because usually after the fabrication there must be have a problem with the product operation cause by inconsiderable factor such as the movement of the lower density fluid in the higher density fluid medium either it is moving in laminar or turbulent shape.

Fig 3.5 Cutting material

Fig 3.6 Main frame of Alternative force converter

3.7 TROUBLESHOOTING

Troubleshooting is a problem solving process while fabricating and operating the prototype. While fabricating and running the product, if there any problem, the first phase examination will applied through the product design by doing some analyzing or redesigning and if there still no problem with that, the second phase examination will followed by inspecting the parts joints and the quality of the component used.

3.8 COMPARISON AND CONCLUSION

After the test had finished, the data gathered from the test result will be compared with the calculation that has been provided before The conclusion will be stated base on the different in calculation and testing value and the factor why this different value occur.

3.9 PROGRESS CONCLUSION

There are nine steps needed to complete this project, it including literature analysis, discussion with supervisor, identify the problem and provide solution, design the force converter mechanism, safety of factor, proposed the best design of the alternative force converter, fabricate the prototype, run the product testing, troubleshooting and comparison and conclusion. All of the steps need to be follow and done in time in order to archive the best result and successfully complete the PSM project. Any mistake and misunderstanding must be avoided or settled as soon as possible because it will effect the overall process flow or in the worse case, the result may can not be archive as expected.

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

In this chapter the result from the FEA analysis, mechanism model simulation and actual test operation result will be assessed and also the selection design and material to be used as a product raw material will be study. The result from the FEA analysis and model simulation will be compared and the best design and raw material will be selected.

The result from Finite Element Analysis, model simulation and actual test result is shown in the figure below. The actual test operation result will be conduct after all the fabrication process completed and the output data gathered will compared to the value of estimation provided.

4.2 CONCEPT DESIGN

Basically this alternative force converter is operating by manipulating the buoyancy force to be converted into torque. So in order to manipulate the buoyancy force into torque, the system is using air traps that attach to the gear chain and multiple gears. All the system is operating under water except the multiple gears. The yellow color in fig 4.1 represent water contain in the tank.

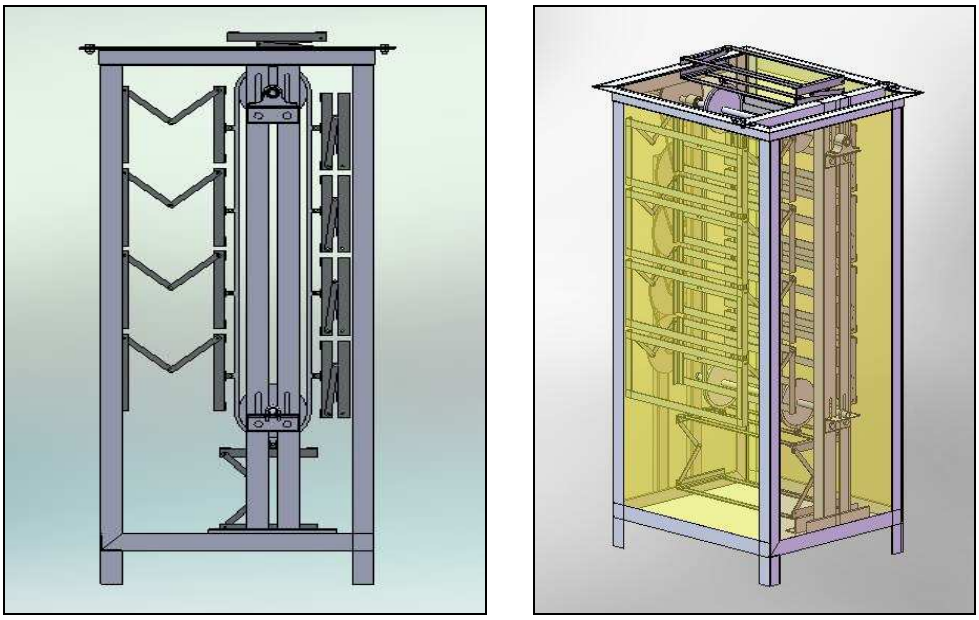


Fig 4.1 Air trap 1st design from side and isometric view

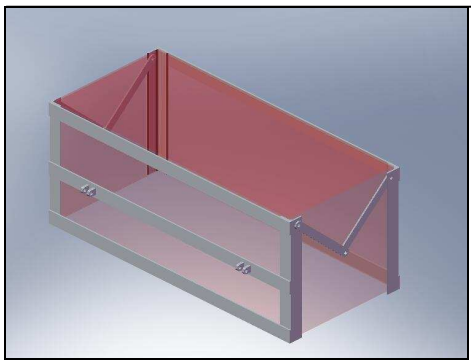


Fig 4.2 Air trap 1st design with plastic cover inside the frame

After 2 month design of alternative force converter, there are 3 concepts has been discovered for the air traps. The two last designs are basically same, but the position of the air trap frame is different as shown in fig 4.3 and 4.4 in order to increase the volume of air contained inside the air trap.

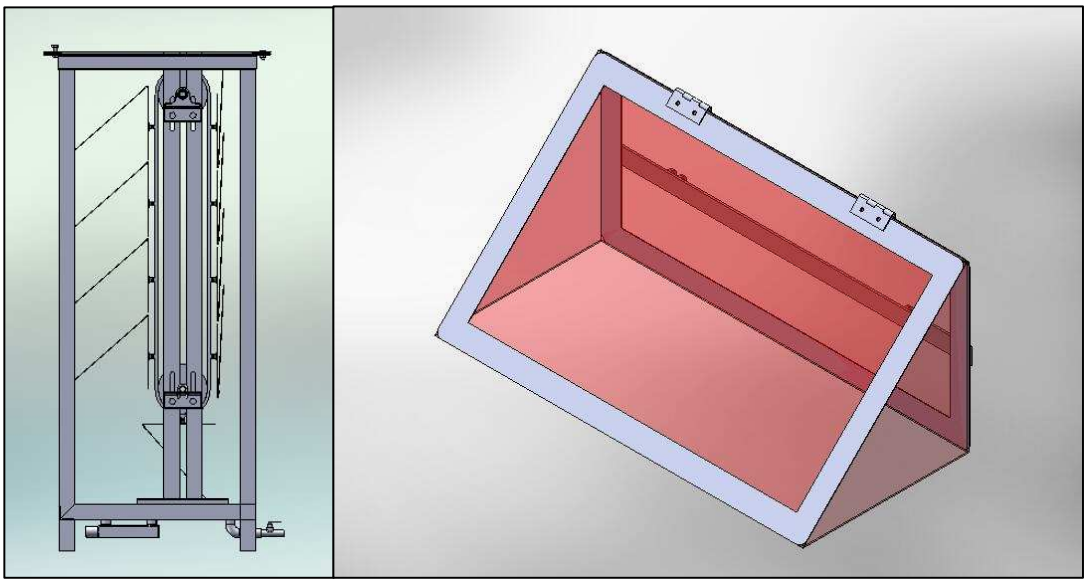


Fig 4.3 Air trap 2nd design in triangle shape

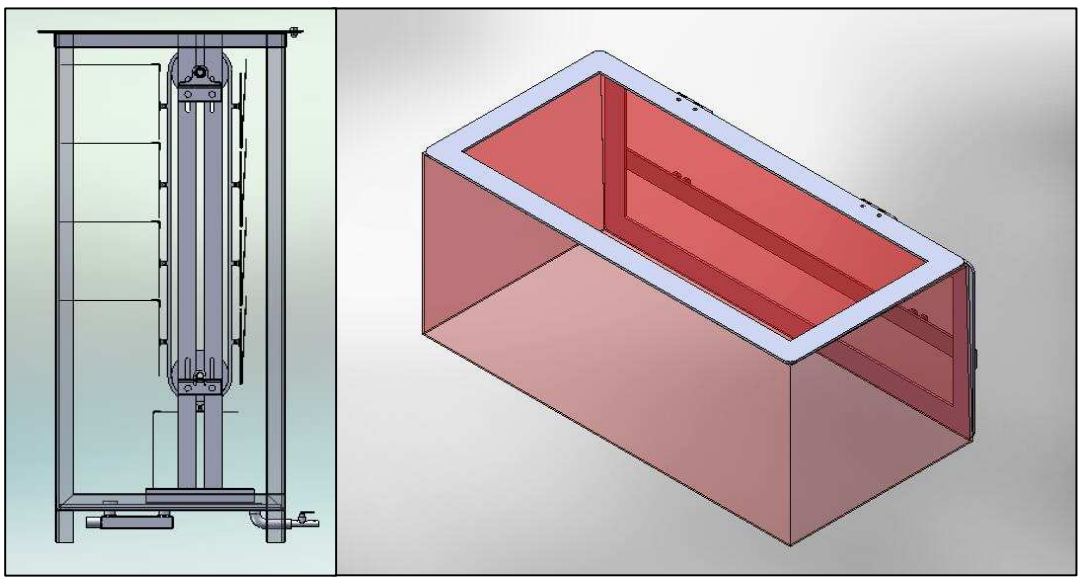


Fig 4.4 Air trap final design to maximize air volume contained

4.2.1 Complete design of Alternative Force Converter

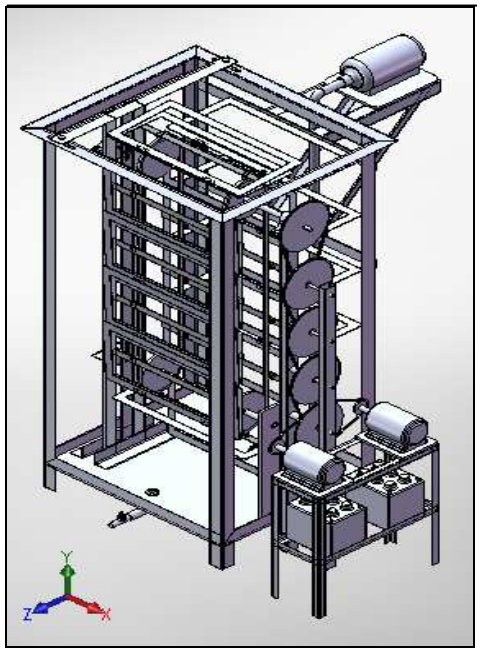


Fig 4.5 Complete design of alternative force converter

Fig 4.6 realistic view of alternative force converter

4.3 HOW THE SYSTEM WORKS

As mentioned before, all the system is in the water medium except the multiple gears. So in order to create buoyancy force, two different densities medium must come together. As shown in fig 4.1 basically there are ten air traps attached in the system, four of them will be in one section with air supplied inside of them and the other four will be in another section with no air inside of them and the other two air traps will be in standby position. The air will be supplied from the bottom of the air traps by air regenerative at speed 210 cubic feet per minute for each air trap as shown in fig 4.7. When there are forces act at one side and zero forces act on another side, it will cause the shaft to turn in one direction parallel to the force acted as shown in fig 4.8. The shaft then attached to the multiple gears to increase the speed of rotation in about 335 times as shown in fig 4.10.

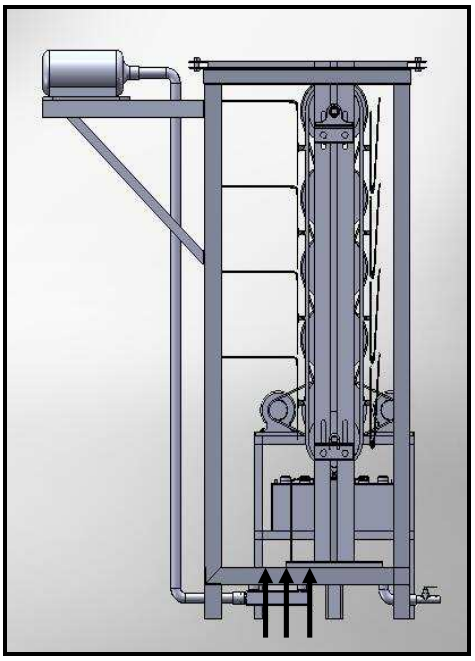


Fig 4.7 Air supplied by air regenerative

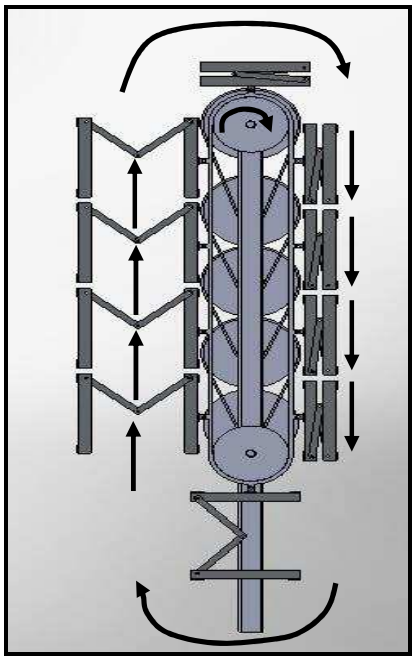


Fig 4.8 Rotation of shaft parallel to the force act direction.

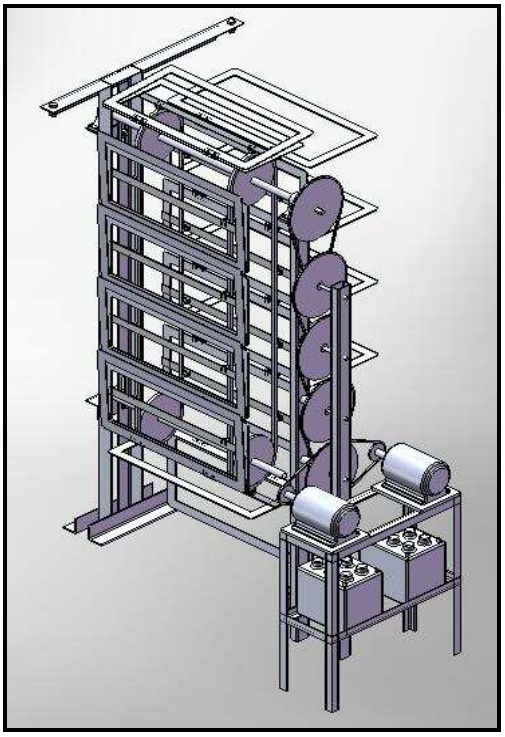


Fig 4.9 Multiple gears isometric view

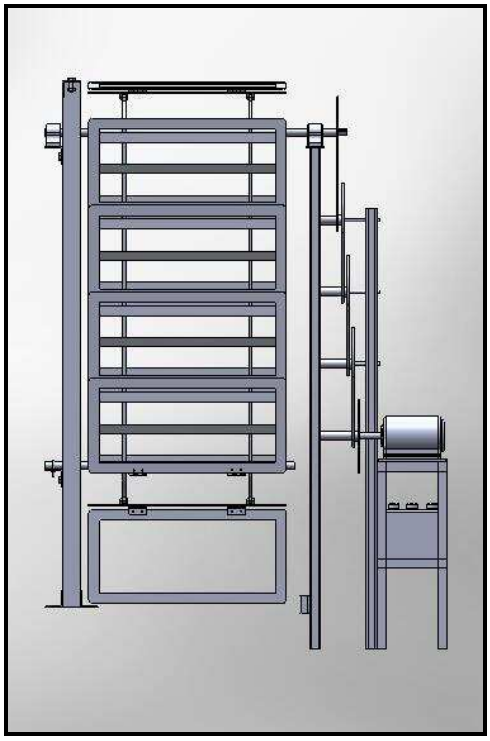


Fig 4.10 Multiple gears side view

4.4 FEA STRESS ANALYSIS TEST RESULT

For the prototype force converter tank shell, I have selected the acrylic (medium – high impact) for front and side cover because it easy for us to look inside the tank and to study overall operation including how the mechanism work compare to the other side using plate Aluminum Alloy 6061 with support. For the regenerative blower supporting frame, iron L bar with triangle shape design have been selected to increase their load supported value.

4.4.1 FEA stress test result - 6mm Acrylic (medium – high impact)

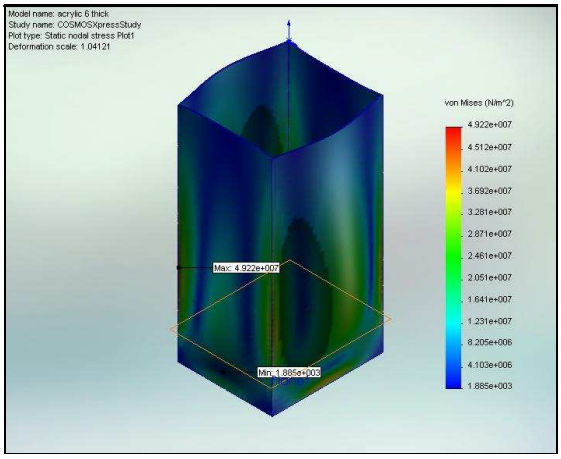


Fig 4.11 FEA stress test

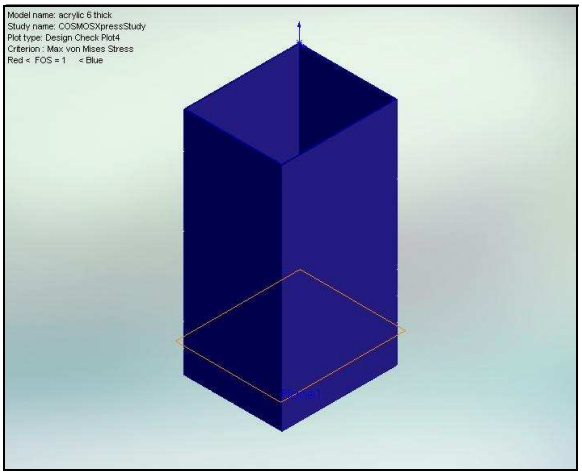


Fig 4.12 Lowest safety of factor value area

With variable pressure applied to every surface inside the shell, the maximum and minimum output of Von Mises stress is 4.92196e+007 N/m^2 and 1885.11 N/m^2 at location (1.15235e-013 mm, -941 mm, 743.65 mm) and (211.217 mm, -1493.65 mm, 654.412 mm). The maximum and minimum displacement output is 143.454 mm and 0 mm at location (6 mm, -898.65 mm, 371.825 mm) and (1.82913e-013 mm, -1493.65 mm, 0 mm). The figure 4.11 shown probability deformation occurs and maximum and

minimum stress area. The lowest factor of safety found in this design is 4.20172 compare to it dynamic safety of factor 2, so it is perfectly safe to be used as a tank shell.

4.4.1 FEA stress test result – plate Aluminum Alloy 6061 with support

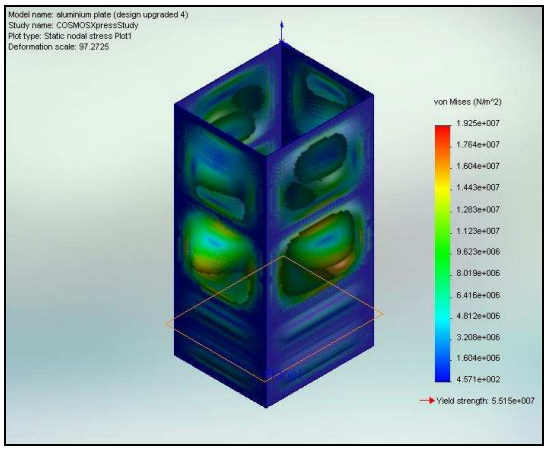


Fig 4.13 FEA stress test

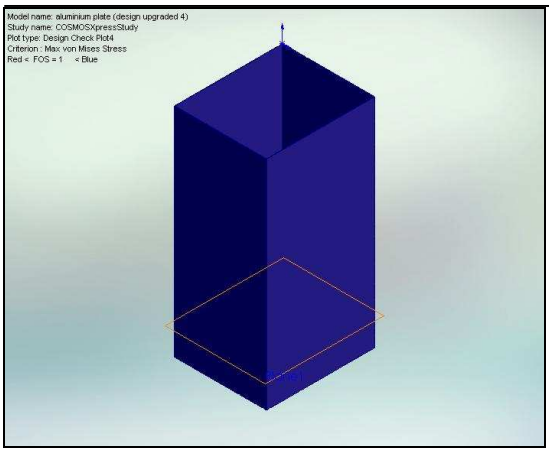


Fig 4.14 Lowest safety of factor value area

With variable pressure applied to every surface inside the shell, the maximum and minimum output of Von Mises stress is 1.92457e+007 N/m^2 and 457.121 N/m^2 at location (632.15 mm, -986.4 mm, 318.231 mm) and (598.447 mm, 0 mm, -7.87735e-005 mm). The maximum and minimum displacement output is 1.53553 mm and 0 mm at location (632.15 mm, -763.354 mm, 371.825 mm) and (49.9999 mm, -1218.65 mm, 0

mm). The figure 4.13 shown probability deformation occurs and maximum and minimum stress area. The lowest factor of safety found in this design is 2.8655 compare to it dynamic safety of factor 2, so it is safe to be used as a tank shell.

4.4.2 FEA stress test result – Regenerative blower supporter

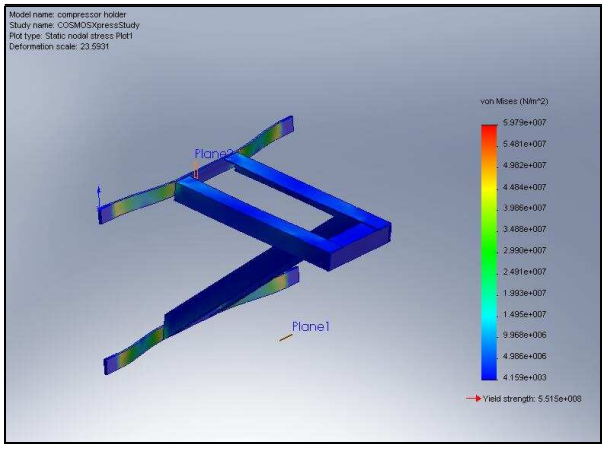


Fig 4.15 FEA stress test

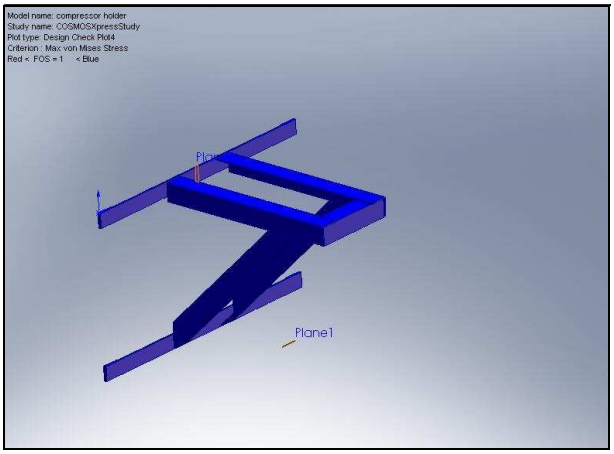


Fig 4.16 Lowest safety of factor value area

With variable pressure applied to every surface inside the shell, the maximum and minimum output of Von Mises stress is 5.9789e+007 N/m^2 and 4159.06 N/m^2 at location (694.134 mm, -447.953 mm, 0 mm) and (750 mm, 0 mm, 5 mm). The maximum and minimum displacement output is 3.4485 mm and 0 mm at location

(300.72 mm, -3 mm, 505 mm) and (0 mm, 0 mm, -3 mm). The figure 4.15 shown probability deformation occurs and maximum and minimum stress area. The lowest factor of safety found in this design is 9.22386 compare to it dynamic safety of factor 3, so this design is very safe to be used for regenerative blower supporter that only have a weight about 20kg.

4.5 RESULT OF AIR FLOW VELOCITY IN THE PIPE

The air flow velocity has been successfully analyzing using FEA COSMOS software. From the data, condition of air at outlet pipe can be determined by using Reynolds's number formula either the air flow at the outlet is turbulent, transition or laminar.

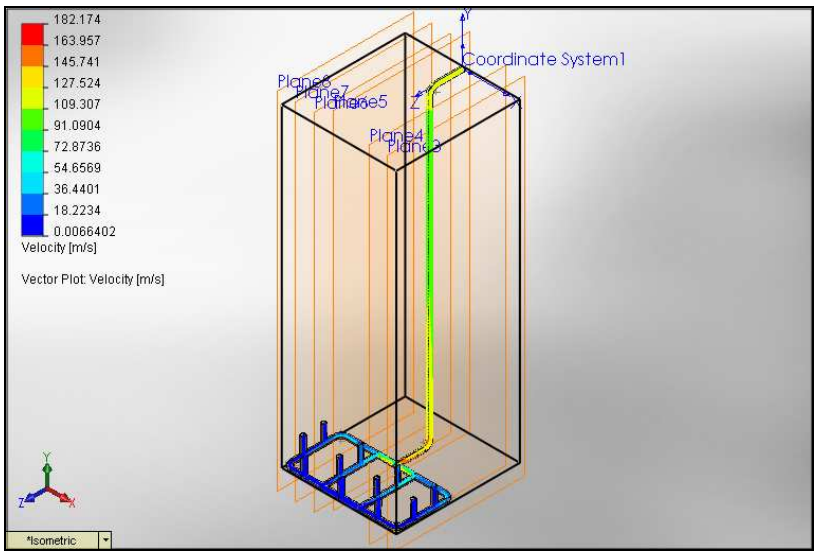
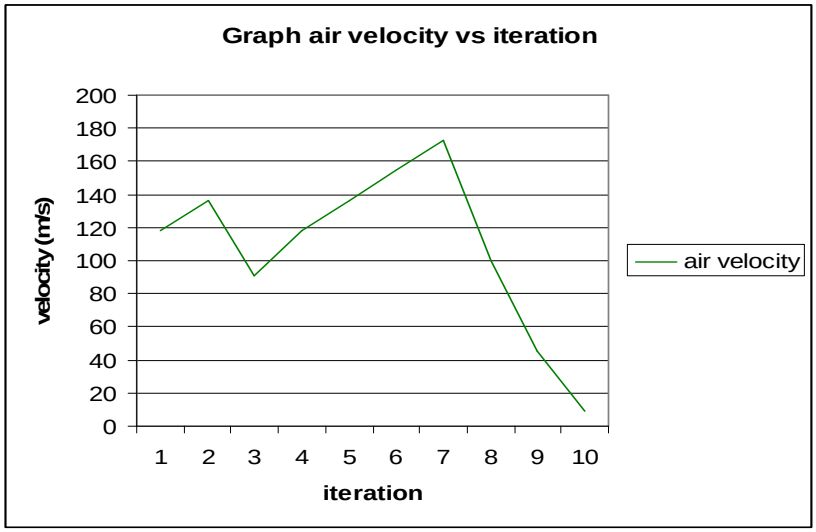


Fig 4.17 Velocity of flow trajectories



Graph 4.1 Velocity of air flow vs iteration

Figure 4.17 shows the value of air flow velocity at different point. The highest value of air flow velocity is at point 7 (173.07 m/s) and the lowest value of air flow velocity is at point 10 (9.12 m/s). The air flow velocity at outlet pipe is 9.12 m/s.

Air flow condition at outlet pipe can be determine using Reynolds's number formula

$$\mathrm{Re} = \frac{\ell v D}{\mu}$$

$\ell = 1.184 \frac{kg}{m^3}$
$v = 9.12\, m/s$
D = 0.022 m
$\mu = 18.27 \times 10^{-6}$

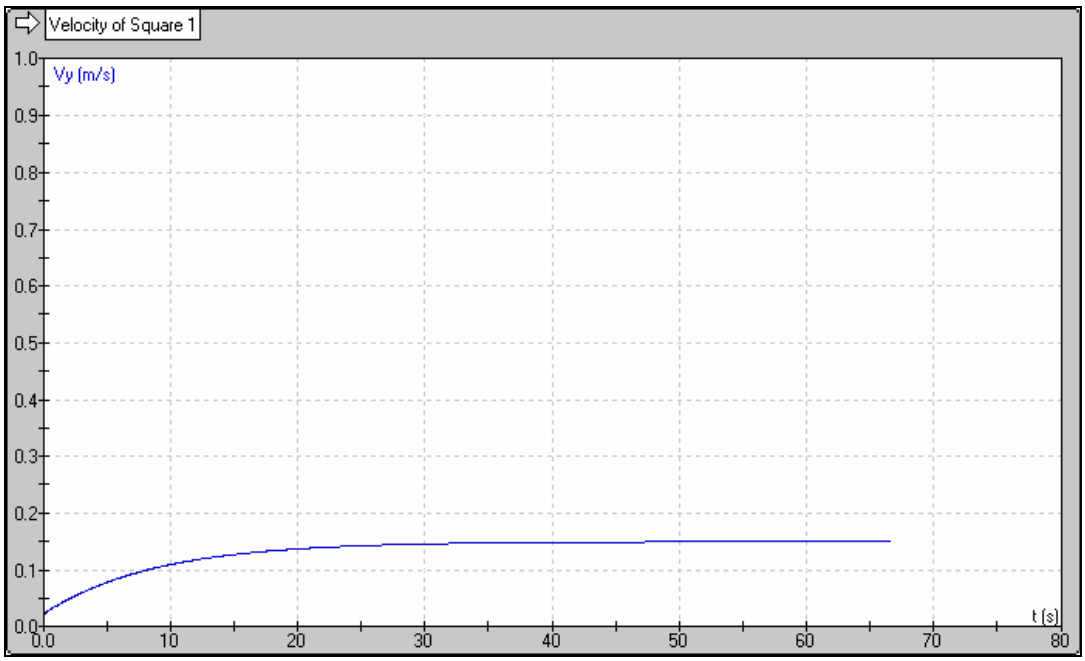
$$\mathrm{Re} = \frac{(1.184)(9.12)(0.022)}{(18.27 \times 10^{-6})}$$

$$\mathrm{Re} = 13002.6$$

So, from the calculation Reynold's number is 13002.6

Re > 4000, turbulent flow.

4.6 Result of air trap speed



Graph 4.2 Speed of moving air trap through a water medium

Result from the analysis shows that the speed of air trap moving upward trough water medium is increasing in every second at the first 10 s and continuously increase the speed until 32 s. The speed of air trap start to stay constant from 32 s until 47 s at 0.14 m/s before the speed increasing a little about 0.01 s become 0.15 m/s at constant condition. The air trap speed is increasing because of the force is continuously supplied toward the air traps in about 347 N per air trap. After a few second, the air traps start to move constantly and this circumstance is because of the force is supplied at constant value and the drag force acted toward the air traps caused some speed limit toward the air traps to move. The buoyancy force is set to 1387.551 N and the drag force is 202.854 N. From this result, the speed of final gear can be determined.

4.7 CALCULATION OF FINAL GEAR SPEED

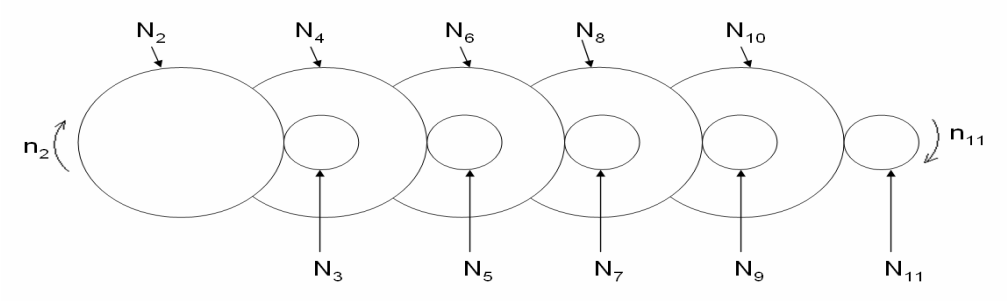


Fig 4.18 Gear trains

Base on analysis result,

V = 0.15 m/s

1st gear perimeter = 2Πr

= 2 x Π x 80 = 502.56 mm @ 0.50256m

1st gear speed = 0.50256

$$1\text{st gear speed} = \frac{0.50256}{0.15}$$

= 1 rev / 3.3504 sec @ 17.908 rpm

n_2 = 17.908 rpm

Hence we notice that gear 2,3,4,5 is an idler, which its tooth numbers cancel because it only effect on the direction of the final gear (gear 6).

$$n_{11} = \frac{N_2}{N_3}\frac{\cancel{N_3}}{\cancel{N_4}}\frac{N_4}{N_5}\frac{\cancel{N_5}}{\cancel{N_6}}\frac{N_6}{N_7}\frac{\cancel{N_7}}{\cancel{N_8}}\frac{N_8}{N_9}\frac{\cancel{N_9}}{\cancel{N_{10}}}\frac{N_{10}}{N_{11}}n_2$$

$$= \frac{N_2}{N_3}\frac{N_4}{N_5}\frac{N_6}{N_7}\frac{N_8}{N_9}\frac{N_{10}}{N_{11}}n_2$$

$$= \frac{48}{15}\frac{48}{15}\frac{48}{15}\frac{48}{15}\frac{48}{15}(17.908rpm)$$

= 3.2 x 3.2 x 3.2 x 3.2 x 3.2 x 17.908

= 6009 rpm

4.8 CALCULATION OF TORQUE REQUIRED TO RUNS THE DYNAMO

$\tau = Fr$

τ = torque

F = Force

r = radius

Calculation:

If the net torque or sum torque is equal to 0, the system is in equilibrium condition.

Torque at the 1st gear

$$\tau_{1st\ gear} = Fr$$

$$\tau_{1st\ gear} = (1387.55)(0.08)$$

$$\tau_{1st\ gear} = 111.004N.m$$

Torque at the final gear

$$\tau_{final\ \ gear} = \tau_{1st\ gear}\left(\frac{1}{\left[\frac{r_2}{r_3}\frac{r_4}{r_5}\frac{r_6}{r_7}\frac{r_8}{r_9}\frac{r_{10}}{r_{11}}\right]}\right)$$

$$\tau_{final\ \ gear} = 111.004\frac{1}{\left[\left(\frac{0.08}{0.0275}\right)^5\right]}$$

$$\tau_{final\ \ gear} = 0.533N.m$$

Minimum torque needed to run the dynamo

$$\tau = Fr$$

$$\tau = (9.81)(0.08)$$

$$\tau = 0.269775N.m$$

Net torque

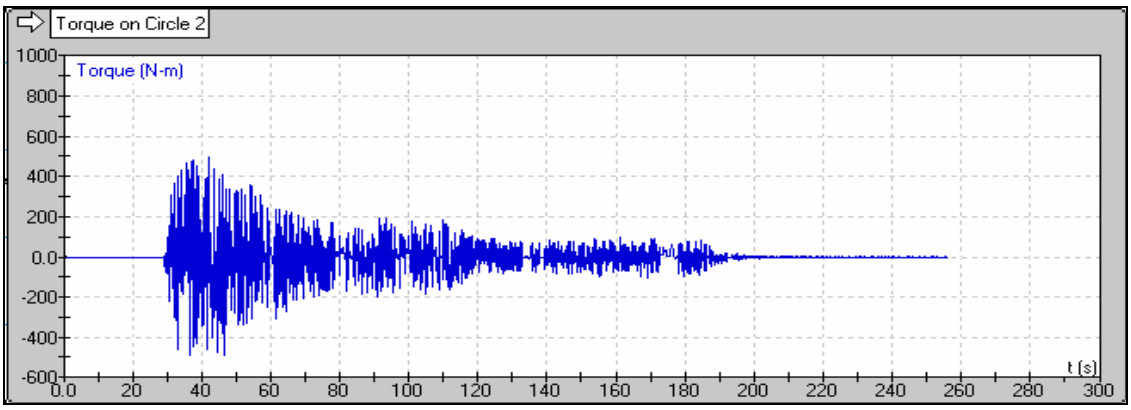
$$\tau_{net} = \tau_{final\ gear} - \tau_{required}$$

$$= 0.533N.m - 0.27N.m$$

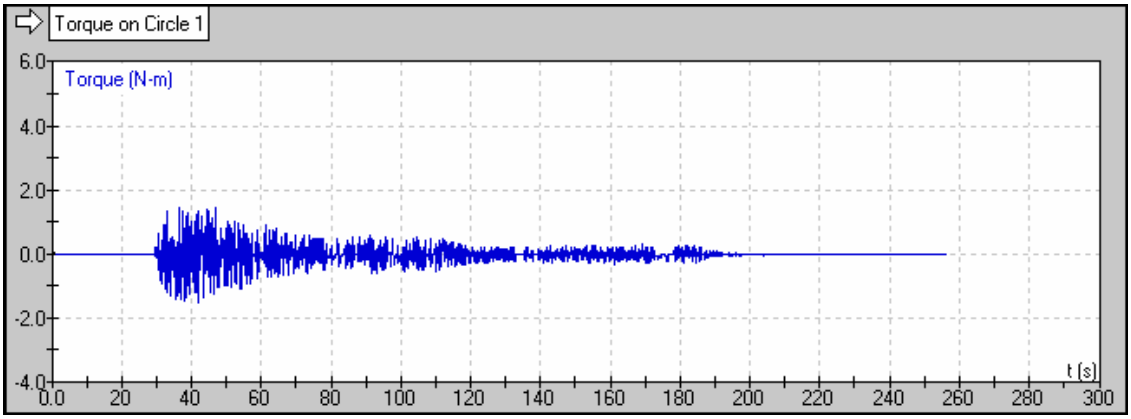
$$= 0.263N.m$$

Net torque is equal to 0.263N.m, so that the system wills run as expected.

4.9 RESULT TORQUE ANALYSIS AT 1ST GEAR AND FINAL GEAR



Graph 4.2 Analysis result torque vs time at 1st



Graph 4.3 Analysis result torque vs time at final gear using

From graph 4.2 shows that the first gear needs minimum 320 N.m torque to initially run the whole gear system and dynamo (load). From calculation, the alternative force converter can supply 111.04 N.m torque at first gear and from the analysis we can see that the gear system with load can run as expected with 110 N.m torque supplied constantly at stable condition (after being run for a few second).

From the analysis, at stable condition the first gear is supplied with 111 N.m and from the graph 4.3 shows the torque at final is about 0.05 N.m. compares to the theory value 0.269775 N.m. This different may because of the gear friction considered in the analysis condition and the momentum of the load.

The system can be run as expected because the net torque at final is not equal to zero. If the net torque value at final gear is equal to zero the system will be in static condition and there is no power produced.

4.10 THEORETICAL POWER OUTPUT

The alternative force converter contains 10 air traps which 4 air trap at the right side (contain air), other 4 at the left side (contain no air), 1 at top side and the last one at the bottom side (refer figure 12). The air traps will rotate continuously due to the constantly air supplied and buoyancy force act on the air traps. The water tank is about 1.5 meter and each air trap is about $0.034375m^3$. The cycle is continuously repeated.
(Refer to Solidwork analysis)
Volume of air in 1 unit air traps = 0.25 x 0.25 x 0.55 = $0.034375m^3$

$F_{buoyancy} = \rho vg$
= 1000 x 0.034375 x 9.81
= 337.22N

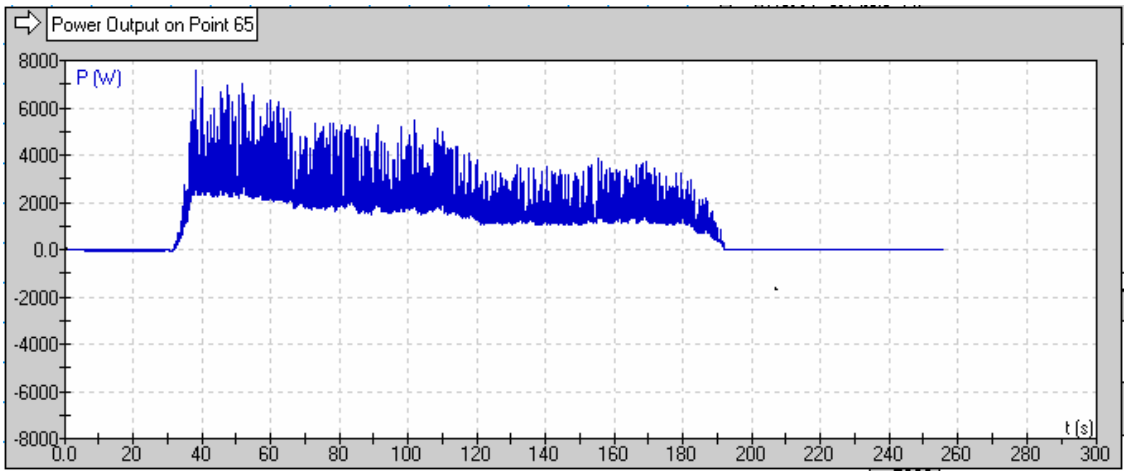
W = mgh
= Fh
= $[(0.034375m^3)\ (9810N)]$ x 1.4m
= 472.108 J

Work done $_{\text{by 4 air traps}}$ = 472.108 J x 4
= 1888.432 J or 1888.432 W

Power consumption by the regenerative blower is 1300 W

W_{output} = 1888.432 W – 1300 W
= 588.432 W
So from the calculation, this device can produce nearly about 600 W per second.

4.11 RESULT OF POWER OUTPUT ANALYSIS



Graph 4.4 Analysis result of power output vs time

As shown in graph 4.4 the power output is higher at the initial point of operation, this is because of the extra torque is applied to the system for a few second in order to neutralize the inertia affect on the system before it gained a momentum in the next few cycles and continuously move in constant speed after several moment.

When 110 N.m torque is supplied at stable condition, the power output is equal to 1750 W at average or 450 W net power output. Compare to the theoretical value of 1888.432 W, the analysis value is slightly lowered about 138.4 W in different. This different may because of the lower torque applied at first gear and the gear friction considered in the analysis.

4.12 FABRICATION

In this fabrication process, it included fabricating main frame, gearing system, piping, wiring, buoyancy taper or air trap, and assembling with existing component such as regenerative blower and dynamo. To reduce the vibration while operating, the cutting material and assembly should be accurate as possible and it depend on the machinery use to fabricate it.

4.12.1 Machinery use

Fig 4.19 Cutting material using automatic band saw machine

Fig 4.20 Cutting material using automated laser cutter

Fig 4.21 Cutting material using disk cutter

Fig 4.22 Make fastener mating point using drilling machine

Fig 4.23 Mating parts using arc welding

4.12.2 Product progress

Fig 4.24 Main frame of alternative force converter

Fig 4.25 Gear slot

Fig 4.26 Regenerative blower supporter

Fig 4.27 Air inlet and water outlet piping system

Fig 4.28 Gearing system assembled

Fig 4.29 Water tank is sealed with silicon to avoid leakage

Fig 4.30 Water tank is covered with acrylic to allow operational observation

Fig 4.31 Water tank with one set air trap assembled

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The objective of this study is to design a new concept of prototype force converter, analyze the mechanism design and fabricate a new concept of prototype alternative force converter. This study shows that the concept and theory of this alternative force converter is acceptable and can be realize in the real world.

I have successfully archive two objective of this project which is design a new concept of alternative force converter and analyze the mechanism of alternative force converter. The last objective can not be done in time because of the financial funding problem, time constraint, and troubleshooting in manufacturing method. I suggest this project should be continued by next PSM student to improve the design and finish the fabrication process.

5.2 RECOMMENDATION

Buoyancy force as an energy resource to produce electricity is a very new idea and the concept to manipulate the energy has been just discovered between 2004 – 2005, so that I suggest to:

I. Improve the concept design of buoyancy force taper to be more efficient.
II. Decrease the total weight of the product.
III. The design must refer to the market component specification to increase the efficiency of the operation beside to avoid problem while fabrication.

This kind of technology has a very good future to monopoly the production of electricity. So that it is very good if there is next PSM student to continue on this research.

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APPENDIX A

SOLIDWORK DATA

Mass Air trap link 1 = Mass Air trap link 2

Mass properties of air trap link 1 (Part Configuration - Default<As Machined>)
Output coordinate System: -- default --
Density = 2.7e-006 kilograms per cubic millimeter
Mass = 0.094 kilograms
Volume = 3.48e-005 cubic meters
Surface area = 0.0226 meters^2

Air trap link 3

Mass properties of air trap link 3 (Part Configuration - Default)
Output coordinate System: -- default --
Density = 2.7e-006 kilograms per cubic millimeter
Mass = 0.0186 kilograms
Volume = 6.89e-006 cubic meters
Surface area = 0.00571 meters^2

Air trap link 5

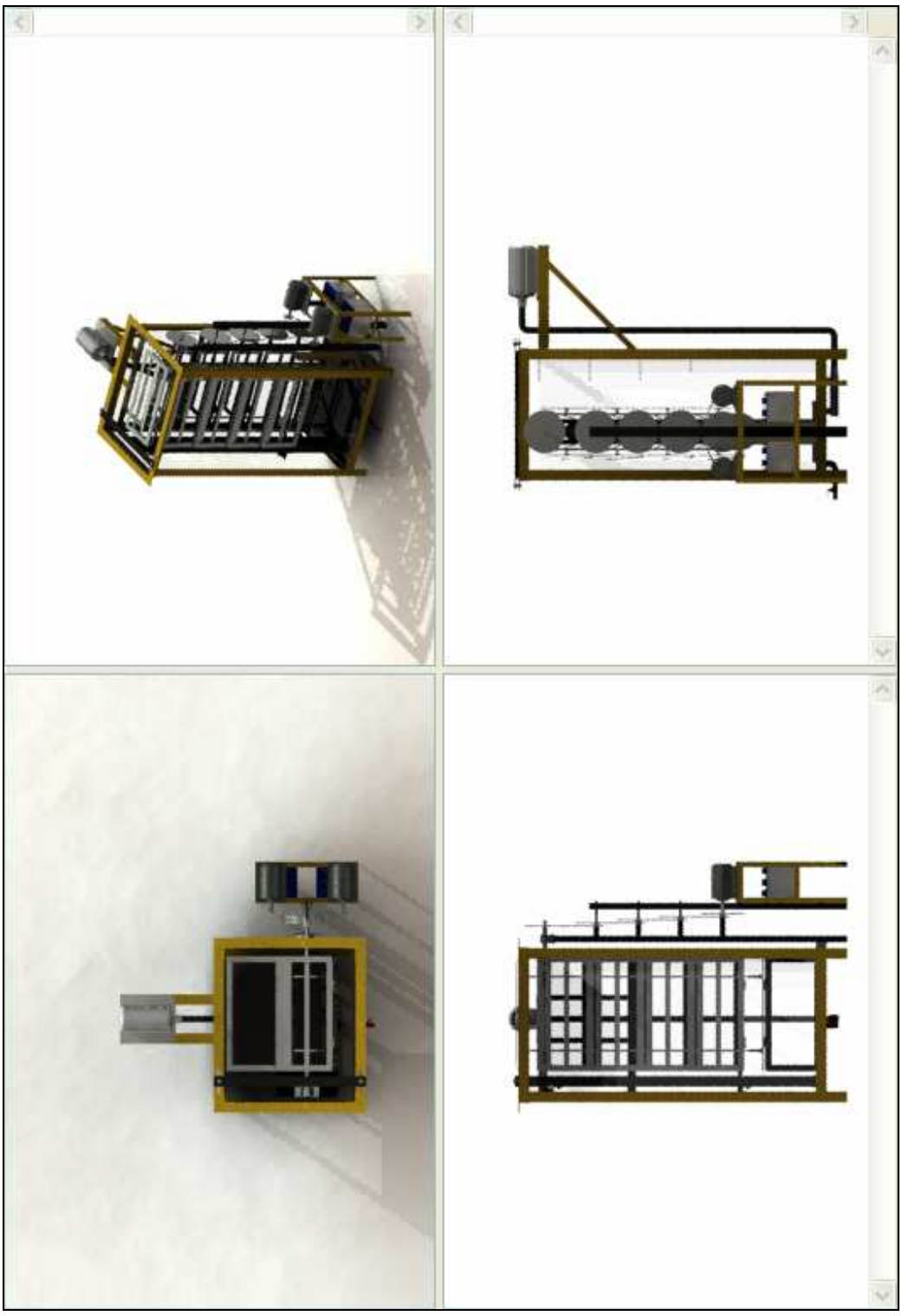
Mass properties of air trap link 5 (Part Configuration - Default)
Output coordinate System: -- default --
Density = 2.7e-006 kilograms per cubic millimeter
Mass = 0.121 kilograms
Volume = 4.5e-005 cubic meters
Surface area = 0.0336 meters^2

Air trap link 4

Mass properties of air trap link 4 (Part Configuration - Default)
Output coordinate System: -- default --
Density = 2.7e-006 kilograms per cubic millimeter
Mass = 0.113 kilograms
Volume = 4.2e-005 cubic meters
Surface area = 0.0315 meters^2

APPENDIX B

RENDER VIEW



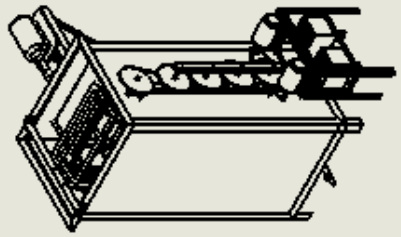
APPENDIX C

BILL OF MATERIAL

BILL OF MATERIAL

ALTERNATIVE FORCE CONVERTER

NO.	PART	MATERIAL	DIMENSION (mm)	UNIT	VENDOR
1	SECONDARY FRAME	1INCH L BAR	(200 X4) + (600 X4) + (250 X4) + (230 X4)	1	-
2	DYNAMO	-	-	2	-
3	GEAR CHAIN	--	-	1	-
4	BALL BEARING	-	D27 d20	4	SKF
5	GEAR CHAIN	-	-	4	-
6	3 PHASE GEAR	-	D200 48TEETH	3	-
7	GEAR HOLDER	R/D	R/D	1	-
8	GEAR CHAIN	-	-	2	-
9	SHAFT	SOLID CYLINDRICAL IRON BAR	D12.5 L860	2	-
10	GEAR	-	D180 44TEETH	4	-
11	ALUMINIUM PLATE 1	ALUMINIUM	560 X 270 X 1.5	10	-
12	ALUMINIUM PLATE 2	ALUMINIUM	560 X 230 X 1.5	10	-
13	HINGE	-	50 X 20	20	-
14	IRON PLATE	IRON	1490 X 623 X 1.5	1	-
15	MAIN FRAME	2 INCH L BAR	(500 X4) + (740 X4) + (640 X4) + (100 X4)	1	-
16	IRON PLATE	IRON	1490 X 720 X 1.5	1	-
17	AIR OUTLET	PVC	-	-	-
18	AIR SUPPLY PIPE	PVC	-	1	-
19	AIR REGENERATIVE SUPPORTER	R/D AFC2	R/D	1	-
20	AIR REGENERATIVE	-	-	1	-
21	ADJUSTABLE SHAFT HOLDER	2 INCH L BAR	200 + 740 + (1500 X2)	1	-
22	NUT M12	-	M12	6	-
23	BOLT M12	-	M12 X 20	4	-
24	LOCK PLATE	2 INCH L BAR	120	2	-
25	NUT M6	-	M6	2	-
26	U LOCK	-	-	1	-
27	BALL BEARING WITH HOLDER	-	D20	2	-
28	BOLT M12	-	M12 X 40	2	-
29	ACRYLIC PLATE	ACRYLIC	1490 X 623 X 1.5	1	-
30	L SHAPE PIPE	PVC	D21 d18	2	-
31	WATER RELEASE PIPE	PVC	-	1	-
32	ACRYLIC PLATE	ACRYLIC	1490 X 720 X 1.5	1	-



PREPARED BY: AHMAD HAFIZ

DATE: 01/07/2008

APPENDIX D

FABRICATION DRAWING